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EP-1557

Position and dose ñ end-to-end test audit phantom for stereotactic radiotherapy

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Purpose/Objective: As stereotactic radiotherapy becomes part of the clinical routine in more and more centres, the need for audit procedures and tools increases. Any audit of stereotactic radiotherapy should address position and delivered dose with equal importance. At the same time, measurement of dose in small stereotactic fields necessitates fine positioning of the probe. Preferably an audit should be uncomplicated and fast to perform. Considering those requirements, a new audit tool is presented, which allows audits to be performed efficiently either by an onsite team or as a postal audit.

Materials and Methods: A Stereotactic Cube phantom has been designed to perform Winston Lutz type position verification measurements and dose measurements in one setup. The phantom comprises a plastic cube with a high density ball in its centre, low density spheres in the periphery, strategically placed gold markers near the posterior and right surfaces and slit-like openings to insert film or other detectors for dose measurement. For the end to end procedure the phantom is first scanned. A treatment plan is created with dose delivered to one or both of the measurement locations using small fields. The fields do not traverse any of the high or low density material. The phantom is setup at the delivery system using 3D imaging. Film has been attached to the phantom at two locations and an orthogonal pair of static beams is delivered for position verification. The exposed films show shadows of the centre ball and the other high density markers. Based on the position of the centre marker on the images relative to the field dimension and to the other markers, the alignment of the phantom in all six dimensions can be verified using image analysis of the scanned films. Alternatively these images can be collected with an MV EPID. Dose measurements are performed with either an ionization chamber or solid state detector, which would have been in place during alignment, or with film, which is inserted into the phantom just prior to exposure.

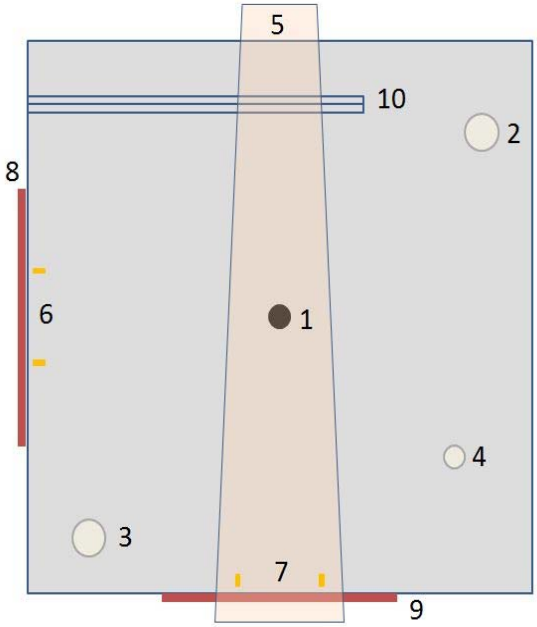

Figure: Axial cut view: high density ball at centre (1), low density objects for kV CBCT alignment in periphery (2-4), simulated beam (5), gold markers (6, 7) to show rotational alignment in MV imaging on film (8, 9) or EPID (not shown) . Insert for dose measurement (10 – film option shown).

Results: Measurements with a prototype of the cube showed excellent suitability for cone beam computed tomography (CBCT) 3D alignment. While high density markers naturally degrade CBCT images through artefacts, the position and good visibility of the low density markers allowed for robust alignment of the cube. MV imaging with film and EPID allowed for clear identification of all markers. Dose measurements were performed with film, while the insert for a small ion chamber is still under construction.

Conclusions: A phantom and methods for an uncomplicated stereotactic audit considering position and dose have been developed and tested.

EP-1558

Adapting the AAPM TG 119 to VMAT treatments and a volumetric phantom

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Purpose/Objective: A treatment planning system (TPS) should be verified in a real 3D situation with rigorous procedures, both for static and rotational modulated techniques. The American Association of Physicists in Medicine Task Group 119 (TG119) proposed a water equivalent square slab phantom (30x30x15 cm^3) with four IMRT tests: Mock Prostate, Head-and-Neck, C-shaped target, and Multi Target. Each test was developed to assess the overall accuracy of planning and delivery of IMRT treatments. TG119 defines also beam arrangements, goals, and methods to analyze dosimetric results. The AAPM phantom is cheap and easily reproducible in every department, but it allows only single point or single planar measurements. In this work

we propose to adapt the TG 119 to VMAT treatments using a different 3D cylindrical dosimetric phantom.

Materials and Methods: TG119 structures were superimposed on the CT images of a cylindrical PMMA phantom surrounding two orthogonal matrices with 1069 total diodes (Delta4 - Scandidos, SWE). TG119 tests were thus calculated and optimized using Monaco 3.3 (Elekta, SWE) and, recently, recalculated with the new version 5, for 6 and 10 MV photon beams, for VMAT techniques, following all plan goals proposed by TG119. Delta4 phantom was used in order to carry out a comparison between measured and planned 3D absolute dose distributions. A 3%, 3mm gamma test (global and local) with a 10% threshold (defined by the isodose line representing 10% of maximum dose) was used for plans analysis and Confidence Limits (CL = |100 – mean| +1.96 * SD) were also generated.

Results/ Goals proposed in TG119 were mostly satisfied for each plan and technique except for the Multi Target, where the dose at 99% of the volume (D99 goal) to the central volume was not achieved. The range of global gamma passing points was 98.4% – 99.7% of total compared points, with a mean percentage value of 99.1 ± 0.5% for all photon energies and all plans thus generating a confidence limit of 2.3% and 1.5% for 6 and 10MV photons beam respectively. The range of local gamma passing points was 96.2% – 98.9%, with a mean percentage value of 97.7 ± 1.1%, now generating a confidence limit of 5.4% and 2.6% for 6 and 10MV respectively.

Conclusions: TG119 structures and plans were found to be adaptable to VMAT treatments and Delta4 phantom, enabling a more exhaustive evaluation procedure, although this solution is also more expensive than the TG119 one. The use of a local gamma stresses all outcomes thus highlighting any local critical area. CLs allow to generate 'in house' reference values to evaluate the overall result of the entire dosimetric process involved in volumetric treatments. Even in the worst case CLs are well lower than the reference one proposed in TG119 (12.4%). Concluding, even if not designed for IMRT, our results showed that TG119 can be a practical commissioning procedure for VMAT therapy too.

EP-1559

Initial clinical experience with EPID-based in-vivo dosimetry for VMAT treatment verification

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Purpose/Objective: An EPID-based in-vivo dosimetry method for 3D-conformal radiotherapy (DISO) and widely used in several Italian Centers has now been expanded to VMAT technique. In this study we prospectively evaluated this transit dosimetry algorithm for complex VMAT treatments and analyzed the issues and challenges for a large-scale adoption in clinical routine.

Materials and Methods/ 20 consecutive patients with head-and-neck tumors and treated with SIB-VMAT using Elekta Precise linacs were enrolled. All plans were generated with Oncentra Masterplan TPS and optimized in dual-arc modality. Three targets were simultaneously irradiated over 30 daily fractions. Doses of 70.5, 60.0 Gy and 55.5 Gy were prescribed to primary tumor, high-risk lymph nodal region and low-risk nodal region, respectively. All patients passed pre-treatment 3%/3mm γ-analysis verification with γ pass-rate of more than 95%. In-vivo tests were evaluate by means of (i) ratio R between daily in-vivo isocenter dose and planned dose and (ii) γ-analysis between EPID integral portal images in terms of percentage of points with γ-value smaller than one ($\gamma_{\%}$) and mean γ-values (γ_{mean}), using a global 3%-3mm criteria. Alert criteria of ±5% for R ratio, $\gamma_{\%}$>90% and γ_{mean}<0.67 were chosen, the last two in order to accept only 10% of the values to exceed 3%/3mm and an average discrepancy of the order of 2%/2mm, respectively.

Results: A total of 368 transit EPID images, two images for each VMAT plan, were acquired during the treatment fractions of 20 patients. 28 images (7.6%) were removed from analysis for image deterioration and/or electronic acquisition failures. The overall mean R ratio was equal to 1.000 ± 0.026 (1SD), with 92.1% of tests within ±5%. The 2D portal images γ-analysis show an overall γ_{mean} of 0.44±0.18 with 90.0% of tests within alert criteria, and a mean $\gamma_{\%}$ equal to 91.9±5.7% with 75.8% of tests within alert criteria. 54 (16%) 2D portal γ-tests showing lower values of γ pass-rate were associated with dose discrepancies. In particular, clinical relevant discrepancies were observed in four patients: a set-up error was detected at the beginning of treatment for one patient and three patients showed major anatomical variations (weight loss/tumor shrinkage) in the second half of treatment. The results are supplied in quasi real-time, with in-vivo tests performed and displayed after only 1 minute from the end of arc delivery.

Conclusions: Our EPID-based in-vivo dosimetry algorithm provided a fast and accurate procedure for VMAT delivery verification in clinical routine. An efficient procedure allow to obtain the results within 1 minute after each arc delivery. This procedure was able to detect when delivery was inconsistent with the original plans, allowing physics and medical staff to promptly act in case of major deviations between measured and planned dose.

EP-1560

A national QA audit for IMRT and VMAT

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